NOTE: Supplemental Materials pages 9-10

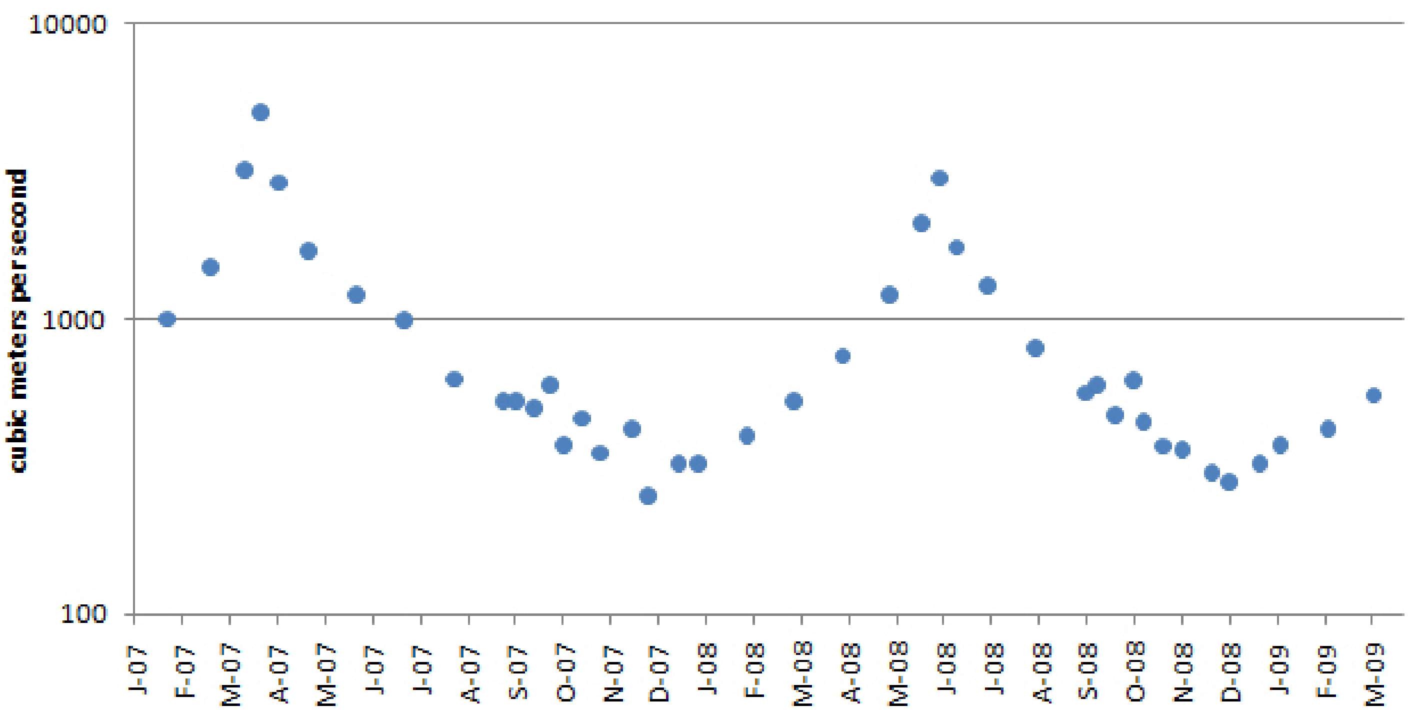
PROBLEM #1 - 25 points **USE UNITS of METERS and DAYS**
Write your answer on the following page. SHOW YOUR WORK

The hydrograph shown below is from a basin that is 5 kilometers by 5 kilometers. The specific yield of the geologic materials average 0.013.

1a) What was the volume of recharge between the 2007 and the 2008 water years?

1b) If all of that water was spread uniformly throughout the basin, how much would the water level change?

To get full credit:
SHOW HOW YOU OBTAIN THE VALUES YOU USED ON THE GRAPH BELOW



PROVIDE CALCULATIONS AND ANSWERS TO PROBLEM 1 HERE
USE UNITS of METERS and DAYS
SHOW YOUR WORK

1a) (20pts) What was the volume of recharge between the 2007 and the 2008 water years?

Remember To get full credit: SHOW HOW YOU OBTAIN THE VALUES YOU USED ON THE GRAPH ON THE PREVIOUS PAGE

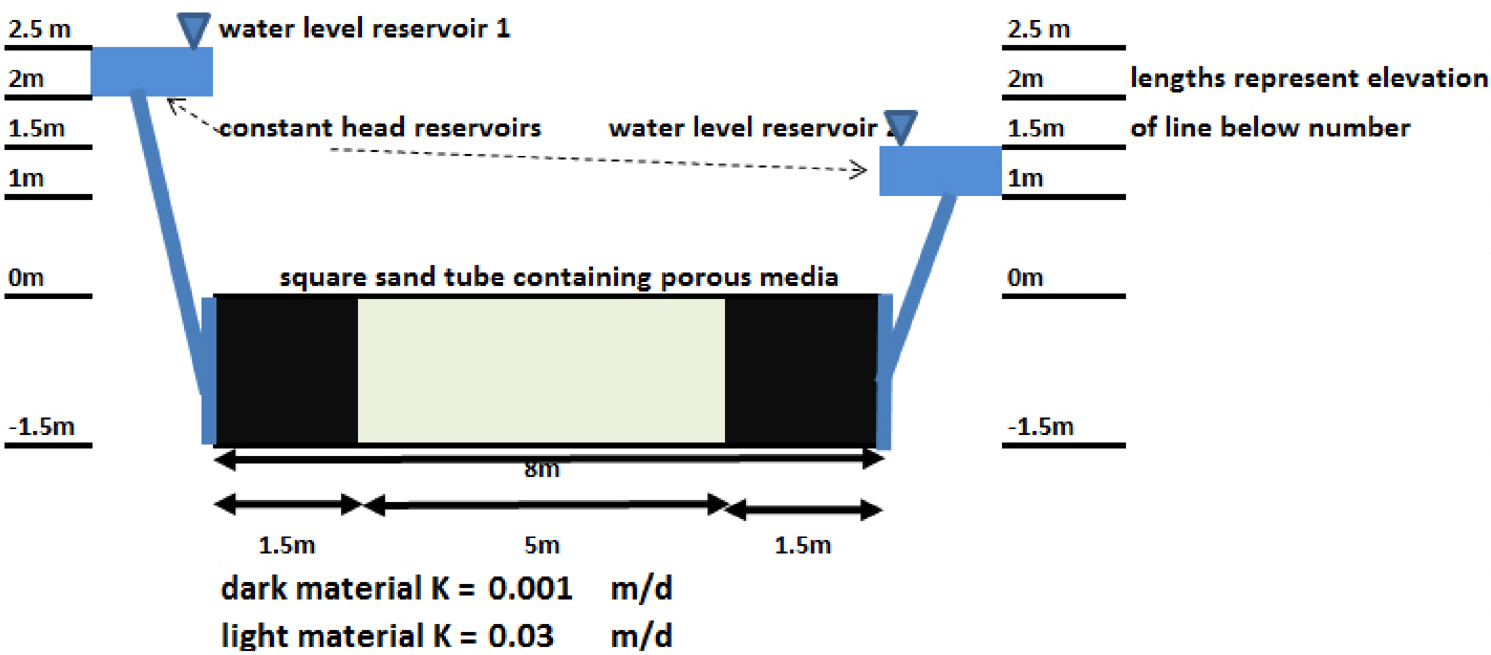
1b) (5pts) If all of that water was spread uniformly throughout the basin, how much would the water level change?

PROBLEM #2 – 25 points **USE UNITS of METERS and DAYS**
Write your answer on the following page. SHOW YOUR WORK

The plastic tube below is square, extending the SAME distance into the paper as it is high in cross section. There are two types of material with hydraulic conductivity as indicated below or the dark and light porous media. Conditions have reached steady state with the water flowing into and out of the reservoirs that enter a porous stone on each end of the tube.

2a) What is the volumetric flow rate through the tube?

2b) What is the head difference across the light colored material in the middle of the tube?



PROVIDE CALCULATIONS AND ANSWERS TO PROBLEM 2 HERE
USE UNITS of METERS and DAYS
SHOW YOUR WORK

2a) (15pts) What is the volumetric flow rate through the tube?

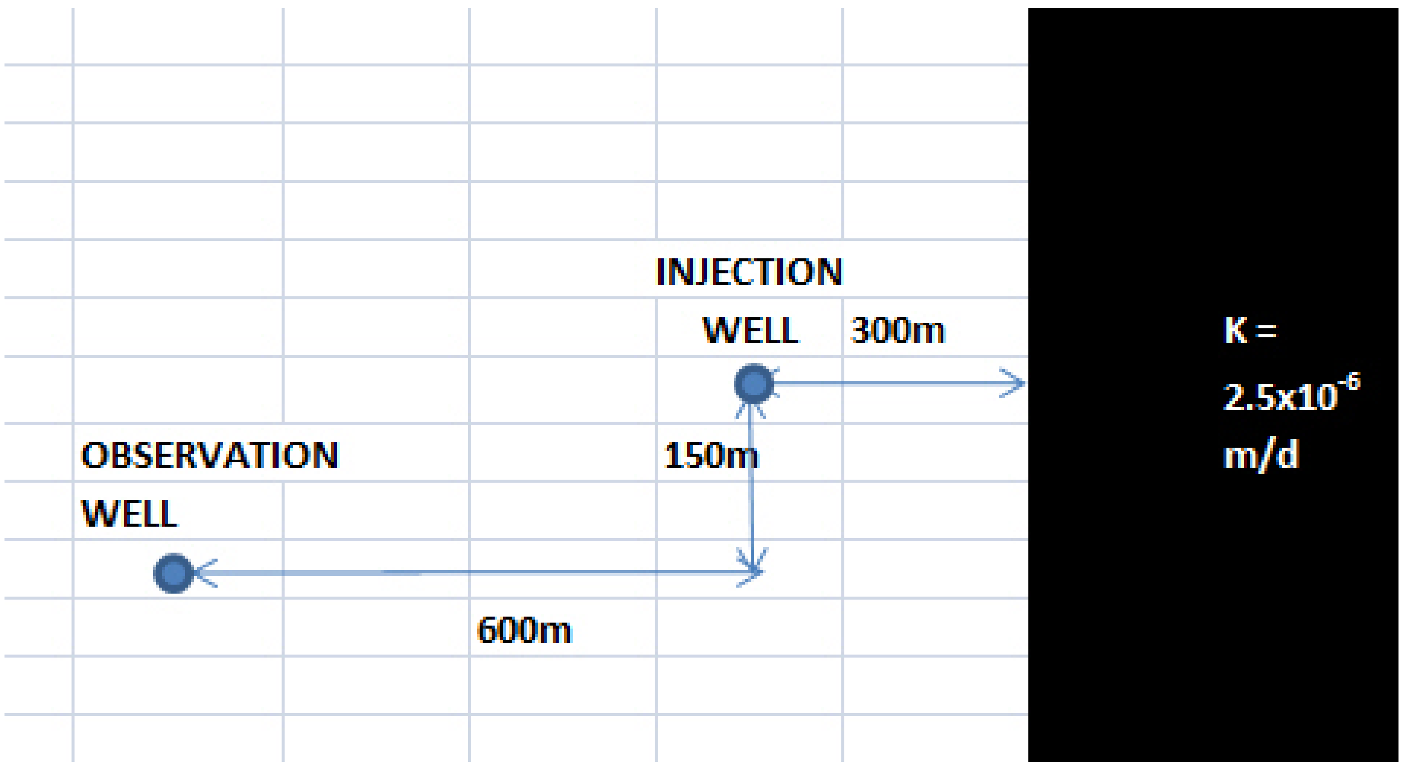
2b) (10pts) What is the head difference across the light colored material in the middle of the tube?

PROBLEM #3 – 25 points **USE UNITS of METERS and DAYS**
Write your answer on the following page. SHOW YOUR WORK

The confined limestone shown in the diagram below is 10 meters thick, has a hydraulic conductivity of 25 m/d and a specific storage of $1x10^{-6}$ m^{-1}. The limestone abuts a crystalline rock formation to the east with a hydraulic conductivity of $2.5x10^{-6}$ m/d. That contact continues for a long distance to the north and south. The limestone is uniform and extensive for a large distance in the other three directions.

1000 cubic meters of water per day is injected in the injection well for 7 days then the injection is stopped.

3a) What is the change in head from the pre-pumping condition at the observation well 1 day after the injection stops?



PROVIDE CALCULATIONS AND ANSWERS TO PROBLEM 3 HERE
USE UNITS of METERS and DAYS
SHOW YOUR WORK

3a) (25pts) What is the change in head from the pre-pumping condition at the observation well 1 day after the injection stops?

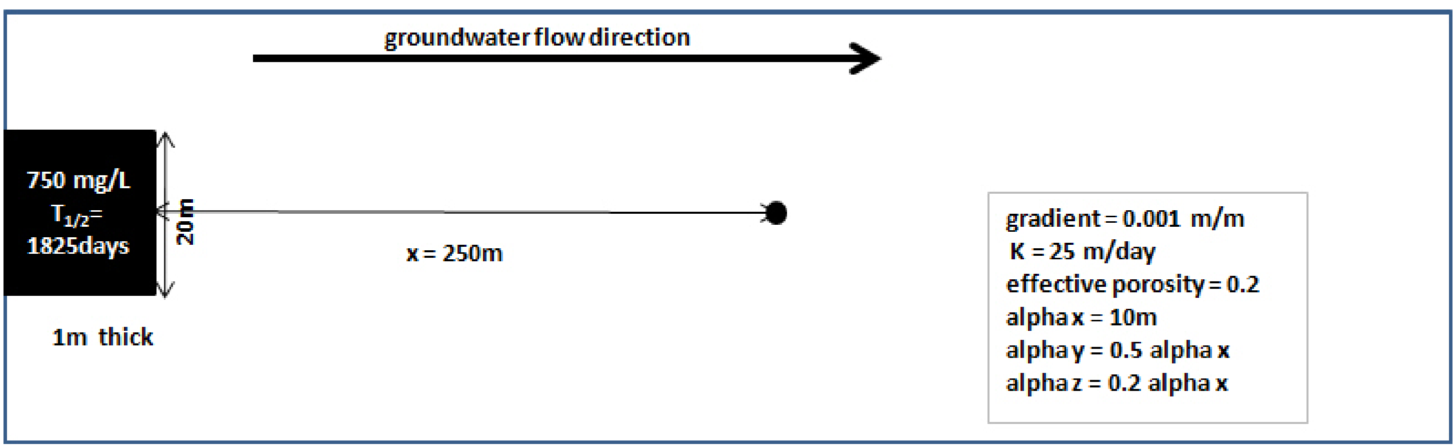
PROBLEM #4 - 25 points **USE UNITS of METERS and DAYS Also MILLIGRAMS and LITERS**

Write your answer on the following page. SHOW YOUR WORK

A 1m thick slab of radioactive material with a half-life of 1825days is 250 m up gradient of my well as illustrated below. The parameters of the flow system and dimensions are given on the diagram. The material continues to raise the groundwater to a concentration of 750 mg/L at the front face of the source indefinitely. A long period of time goes by.

4a) What is the concentration at the well?

4b) What do you think constitutes a long period of time? You will only get credit for this answer if you properly explain how you choose the time.



PROVIDE CALCULATIONS AND ANSWERS TO PROBLEM 4 HERE
USE UNITS of METERS and DAYS
Also MILLIGRAMS and LITERS
SHOW YOUR WORK

4a) (23pts) What is the concentration at the well?

4b) (2pts) What do you think constitutes a long period of time? You will only get credit for this answer if you properly explain how you choose the time.

u	$W(u)$	u	$W(u)$	u	$W(u)$	u	$W(u)$
1×10^{-10}	22.45	7×10^{-8}	15.90	4×10^{-5}	9.55	1×10^{-2}	4.04
2	21.76	8	15.76	5	9.33	2	3.35
3	21.35	9	15.65	6	9.14	3	2.96
4	21.06	1×10^{-7}	15.54	7	8.99	4	2.68
5	20.84	2	14.85	8	8.86	5	2.47
6	20.66	3	14.44	9	8.74	6	2.30
7	20.50	4	14.15	1×10^{-4}	8.63	7	2.15
8	20.37	5	13.93	2	7.94	8	2.03
9	20.25	6	13.75	3	7.53	9	1.92
1×10^{-9}	20.15	7	13.60	4	7.25	1×10^{-1}	1.823
2	19.45	8	13.46	5	7.02	2	1.223
3	19.05	9	13.34	6	6.84	3	0.906
4	18.76	1×10^{-6}	13.24	7	6.69	4	0.702
5	18.54	2	12.55	8	6.55	5	0.560
6	18.35	3	12.14	9	6.44	6	0.454
7	18.20	4	11.85	1×10^{-3}	6.33	7	0.374
8	18.07	5	11.63	2	5.64	8	0.311
9	17.95	6	11.45	3	5.23	9	0.260
1×10^{-8}	17.84	7	11.29	4	4.95	1×10^{0}	0.219
2	17.15	8	11.16	5	4.73	2	0.049
3	16.74	9	11.04	6	4.54	3	0.013
4	16.46	1×10^{-5}	10.94	7	4.39	4	0.004
5	16.23	2	10.24	8	4.26	5	0.001
6	16.05	3	9.84	9	4.14		

Appendix 3 Values of the functions $W(u, r/B)$ for various values of u

u \ r/B	0.002	0.004	0.006	0.008	0.01	0.02	0.04	0.06	0.08	0.1	0.2	0.4	0.6	0.8	1	2	4	6	8
0	12.7	11.3	10.5	9.89	9.44	8.06	6.67	5.87	5.29	4.85	3.51	2.23	1.55	1.13	0.842	0.228	0.0223	0.0025	0.0003
0.000002	12.1	11.2	10.5	9.89	9.44														
0.000004	11.6	11.1	10.4	9.88	9.44														
0.000006	11.3	10.9	10.4	9.87	9.44														
0.000008	11.0	10.7	10.3	9.84	9.43														
0.00001	10.8	10.6	10.2	9.80	9.42	8.06													
0.00002	10.2	10.1	9.84	9.58	9.30	8.06													
0.00004	9.52	9.45	9.34	9.19	9.01	8.03	6.67												
0.00006	9.13	9.08	9.00	8.89	8.77	7.98	6.67												
0.00008	8.84	8.81	8.75	8.67	8.57	7.91	6.67												
0.0001	8.62	8.59	8.55	8.48	8.40	7.84	6.67	5.87	5.29										
0.0002	7.94	7.92	7.90	7.86	7.82	7.50	6.62	5.86	5.29										
0.0004	7.24	7.24	7.22	7.21	7.19	7.01	6.45	5.83	5.29	4.85									
0.0006	6.84	6.84	6.83	6.82	6.80	6.68	6.27	5.77	5.27	4.85									
0.0008	6.55	6.55	6.54	6.53	6.52	6.43	6.11	5.69	5.25	4.84									
0.001	6.33	6.33	6.32	6.32	6.31	6.23	5.97	5.61	5.21	4.83	3.51								
0.002	5.64	5.64	5.63	5.63	5.63	5.59	5.45	5.24	4.98	4.71	3.50								
0.004	4.95	4.95	4.95	4.94	4.94	4.92	4.85	4.74	4.59	4.42	3.48	2.23							
0.006	4.54				4.54	4.53	4.48	4.41	4.30	4.18	3.43	2.23							
0.008	4.26				4.26	4.25	4.21	4.15	4.08	3.98	3.36	2.23							
0.01	4.04				4.04	4.03	4.00	3.95	3.89	3.81	3.29	2.23	1.55	1.13					
0.02	3.35				3.35	3.35	3.34	3.31	3.28	3.24	2.95	2.18	1.55	1.13					
0.04	2.68				2.68	2.68	2.67	2.66	2.65	2.63	2.48	2.02	1.52	1.13	0.842				
0.06	2.30				2.30	2.29	2.29	2.28	2.27	2.26	2.17	1.85	1.46	1.11	0.839				
0.08	2.03					2.03	2.02	2.02	2.01	2.00	1.94	1.69	1.39	1.08	0.832				
0.1	1.82						1.82	1.82	1.81	1.80	1.75	1.56	1.31	1.05	0.819	0.228			
0.2	1.22						1.22	1.22	1.22	1.22	1.19	1.11	0.996	0.857	0.715	0.227			
0.4	0.702						0.702	0.702	0.701	0.700	0.693	0.665	0.621	0.565	0.502	0.210			
0.6	0.454						0.454	0.454	0.454	0.453	0.450	0.436	0.415	0.387	0.354	0.177	0.0222		
0.8	0.311						0.311	0.310	0.310	0.310	0.308	0.301	0.289	0.273	0.254	0.144	0.0218		
1	0.219									0.219	0.218	0.213	0.206	0.197	0.185	0.114	0.0207	0.0025	
2	0.049										0.049	0.048	0.047	0.046	0.044	0.034	0.011	0.0021	0.0003
4	0.0038											0.0038	0.0037	0.0037	0.0036	0.0031	0.0016	0.0006	0.0002
6	0.0004														0.0004	0.0003	0.0002	0.0001	0
8	0																		0

Source: After M. S. Hantush, "Analysis of Data from Pumping Test in Leaky Aquifers," *Transactions, American Geophysical Union*, 37 (1956):702–14.

Complementary Error Function (erfc)

$$\operatorname{erf}(\beta) = \frac{2}{\pi} \int_0^\beta e^{-\epsilon^2}\, d\epsilon$$

$$\operatorname{erf}(-\beta) = -\operatorname{erf} \beta$$

$$\operatorname{erfc}(\beta) = 1 - \operatorname{erf}(\beta)$$

β	erf (β)	erfc (β)
0	0	1.0
0.05	0.056372	0.943628
0.1	0.112463	0.887537
0.15	0.167996	0.832004
0.2	0.222703	0.777297
0.25	0.276326	0.723674
0.3	0.328627	0.671373
0.35	0.379382	0.620618
0.4	0.428392	0.571608
0.45	0.475482	0.524518
0.5	0.520500	0.479500
0.55	0.563323	0.436677
0.6	0.603856	0.396144
0.65	0.642029	0.357971
0.7	0.677801	0.322199
0.75	0.711156	0.288844
0.8	0.742101	0.257899
0.85	0.770668	0.229332
0.9	0.796908	0.203092
0.95	0.820891	0.179109
1.0	0.842701	0.157299
1.1	0.880205	0.119795
1.2	0.910314	0.089686
1.3	0.934008	0.065992
1.4	0.952285	0.047715
1.5	0.966105	0.033895
1.6	0.976348	0.023652
1.7	0.983790	0.016210
1.8	0.989091	0.010909
1.9	0.992790	0.007210
2.0	0.995322	0.004678
2.1	0.997021	0.002979
2.2	0.998137	0.001863
2.3	0.998857	0.001143
2.4	0.999311	0.000689
2.5	0.999593	0.000407
2.6	0.999764	0.000236
2.7	0.999866	0.000134
2.8	0.999925	0.000075
2.9	0.999959	0.000041
3.0	0.999978	0.000022

NOTE:

for beta > 3, use
erf(beta) = 1.0

for beta < 0.05, use
erf(beta) = 1.13*beta